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ABSTRACT

In spite of the continued focus on problem solving, American elementary and middle grades schoolchildren are perceived to be ineffective problem solvers. This paper reports the results of a survey of (n=744) kindergarten through eighth grade teachers and interviews and observations of a primary and an intermediate master teacher designed to answer the following questions: (1) What is the current nature of mathematical problem-solving instruction in Arizona K-8 classrooms, and (2) To what extent do reported classroom practices in problem-solving instruction reflect the recommendations of the National Council of Teachers of Mathematics (NCTM) and others? Survey results in the areas of instructional practices, word problem sources, student and self-assessments, problem-solving strategies, and beliefs are reported. Interview results include the topics of problem-solving instruction, definition of problem solving, use of textbooks, group work, assessment, calculators, and advice to other teachers. Three responses indicated possible misalignment with the NCTM Standards: (1) Use of manipulatives dropped off dramatically as grade level increased; (2) Teachers responded positively to students' needing to know the key word approach to problem solving; and (3) There was a discrepancy between the perceived usefulness of calculators and the actual use of calculators. (MKR)

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Beliefs and Practices in Mathematical Problem Solving Instruction: K-8

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Beliefs and Practices in Mathematical Problem Solving Instruction: K-8

In 1980 the National Council of Teachers of Mathematics (NCTM) declared problem solving as the first order of importance for mathematics instruction in their *Agenda for Action*. The NCTM maintained their commitment to the importance of problem solving instruction in the *Curriculum and Evaluation Standards for School Mathematics* (1989) again ranking problem solving as the top priority of mathematics education for the 1990s.

This sustained focus on problem solving has resulted in a large amount of research on problem solving instruction (e.g., Kloosterman, 1992; Duren & Cherrington, 1992; Proudfit, 1992; Carey, 1991) as well as articles for practitioners that offer recommendations for instructional techniques that promote problem solving ability (e.g., Silverman, Winograd, and Strohauer, 1992; Kroll, Masingila & Mau, 1992; Maher & Martino, 1992) .

Unfortunately, in spite of the continued focus on problem solving, American elementary and middle grade school children are perceived to be ineffective problem solvers. Teachers report that many students merely "give-up" when confronted with problem solving situations. This lack of achievement coupled with the national interest in problem solving and the plethora of information available to assist teachers in problem solving instruction leads to several questions, two of which are central to this research project. First, what is the current nature of mathematical problem solving instruction in Arizona K-8 classrooms? Second, to what extent do reported classroom practices in problem solving instruction reflect the recommendations of the National Council of Teachers of Mathematics and others?

Method

Questionnaire development

Questionnaire development began with a review of the literature to identify recommendations about instructional strategies for developing student problem solving ability. These recommendations were the basis for writing Likert-type items that

attempted to gauge teachers' frequency of use of these instructional strategies, teachers' perceptions of the usefulness of specific strategies for problem solving, teachers' confidence in using those strategies, and teachers' beliefs about specific recommendations for problem solving instruction. Additional items addressed sources of problems, time spent weekly on problem solving, demographic data about the teachers, teachers' self-assessment of their own problem solving ability, and teachers' assessment of their students' problem solving ability. The questionnaire was piloted with a small group (n=17) of elementary school teachers to evaluate its clarity and freedom from ambiguity. The questionnaire was revised based on the pilot administration.

Sample

During the 1992-1993 school year 60 randomly selected elementary and unified school districts throughout Arizona were invited to participate in this survey study. Of those invited, 29 agreed to participate. Copies of the questionnaire were sent to a contact person at each of the cooperating school districts. The contact person distributed the questionnaires to all teachers at the participating schools who taught mathematics as part of their regular responsibilities. The completed questionnaires were collected and either picked up by, or mailed to, the researcher. Although gender, degree, and grade level of teaching assignment were included in the questionnaire, the names of the participants remained anonymous.

After the collection of the survey data, two teachers, one from the primary grades (K-3) and the other from the middle grades (7-8) in one of participating school districts were identified as master teachers by the district mathematics curriculum coordinator. Those teachers were interviewed and then observed on three separate occasions about mathematical problem solving. One was teaching third grade and the other was teaching eighth grade. In that these teachers were recognized as exemplary teachers for

mathematics, it was expected that they would approach problem solving from a perspective congruent with recommendations.

Survey Results

The respondents consisted of 744 kindergarten through eighth grade teachers, 631 females and 113 males. Bachelor's degrees were the highest earned for 449 of the teachers, 292 had earned Master's degrees or higher. Seventy-three percent of the teachers responding taught in closed classrooms, 18% departmentalized, and three percent were teaching Special Education classes.

The data were subdivided into three groups by grade level: K-3 (primary grades), 4-6 (intermediate grades), and 7-8 (middle grades). Descriptions of the teachers by groups are contained in Table 1.

Insert Table 1 About Here

About half of the respondents were from the primary grades. Female teachers accounted for 85% of those responding, 96% at the K-3 level. Although the proportion of females decreased with increased grade level, female teachers still accounted for over half of the middle grade teachers. About 60% of the teachers surveyed reported having a Bachelor's degree. There was no apparent pattern involving highest degree earned and grade level. At the K-3 level about 90% of teachers were in closed classrooms. More departmentalization was evident in the 4-6 grade (20%) and departmentalization is dominant (83%) in the 7-8 grade.

Those responding were a relatively experienced group of teachers with a mean of more than ten years of teaching experience (see Table 2) at all the grade levels. The mean time at current grade level indicates a stable teaching force. Teachers at both the K-3 and 4-6 levels reported teaching mathematics about five hours a week, about one hour per day. The

mean hours per week at the 7-8 level were higher, due to departmentalization. The hours per week on mathematics problem solving at all three level accounted for 40 percent of total mathematics instructional time at both the K-3 and the 4-6 levels decreasing to 30 percent at the 7-8 level, a result confounded by departmentalization in the middle grades.

Insert Table 2 About Here

At both the K-3 and the 4-6 levels, teachers averaged slightly more than one math inservice day per year. At the 7-8 level the average was 1.5 days. This might be a function of the content focus more prevalent at the middle grades. It is more likely that a person teaching more mathematics than other subjects, in many cases exclusively mathematics, would be more likely to attend inservice on mathematics. The remaining items on the questionnaire required teachers to respond on Likert-type scales to a variety of statements about mathematical problem solving instruction.

Instructional Practices

Teachers were asked to respond concerning their frequency of use of five recommended instructional strategies for problem solving instruction. Response choices were: 5-most of the time, 4-often, 3-sometimes, 2-not very often, and 1-not at all. The mean responses by grade level appear in Table 3. High means on these items indicate alignment with recommendations for problem solving instruction.

Insert Table 3 About Here

All three grade level groups had a narrow range of means (3.28 to 3.94) for the items about using groups, having students explain how they arrived at answers, asking for different ways to solve the same problem, and justifying solutions. Mean responses to the

statement about students using manipulatives to solve problems ranged from 4.09 (K-3) to 2.27 (7-8).

Word Problem Sources

Teachers were asked to respond concerning their perception of the usefulness of selected sources for word problems. Their choices were: 5-very useful, 4-useful, 3-average, 2-not very useful, and 1-not at all useful. Teachers at the primary grade levels rated textbook usefulness below average (2.79). All other means ranged from 3.45 to 4.16 (See Table 4). Examples of supplemental materials included; material from other subjects to work out real problems, student created problems, Math Their Way, videos, workbooks, and teaching store supplies.

Insert Table 4 About Here

Student and Self Assessments

Teachers were asked to rate their own problem solving and their students' problem solving on a traditional four-point grading scale (A-4, B-3, etc.).

Insert Table 5 About Here

Teachers tended to rate themselves in the B range (3.5-2.5) for problem solving ability, instruction, and motivation to teach problem solving. Most ratings for students were in the C range (2.5-1.5). Ratings for student interest in problem solving declined from 2.62 (K-3) to 1.97 (7-8).

Problem Solving Strategies

Teachers were asked to respond on a five point scale (5= very useful, 4=useful, 3= uncertain, 2= not very useful, and 1= not at all useful) about the usefulness of 20 specific problem solving strategies that appear in textbooks and other sources (e.g., look for a pattern, draw a diagram). They also were asked to respond on a five point scale (5- very confident, 4-confident, 3- uncertain, 2- not very confident, and 1- not at all confident) about their confidence in using those same problem solving strategies. Teachers' ratings of the usefulness of the strategies ranged from 3.45 to 4.75. Ratings for confidence were also high and ranged from 3.61 to 4.68.

Beliefs

Teachers were asked about their agreement with statements about problem solving (5- strongly agree, 4- agree, 3= undecided, 2- disagree, and 1- strongly disagree). Some statements were phrased to be contrary to recommended instruction. Mean responses to those statements appear in Table 6. Mean responses to most of the items were in the 2 to 3 range. An exception was that teachers tended to agree that students need to know the key word approach to problem solving (3.44-3.88).

Insert Table 6 About Here

Others questions were phrased so that agreement would indicate alignment with recommendations. The mean responses for these questions appear in Table 7. Teachers responses ranged from 3.20 to 4.05 range with the exception of an item about calculator use ranging from 2.24 to 3.06.

Insert Table 7 About Here

Teacher Interviews

Each of the two teachers was interviewed on three separate occasions. The interviews were audio-taped and later transcribed. The transcriptions were examined for comments that seemed to summarize the teachers' beliefs and practices about problem solving instruction. Those comments were then grouped into emergent categories. The extracted comments by category for each teacher separately appear below.

Problem Solving Instruction

Third Grade Teacher

- explain the problem to the whole class, let the students work in groups, talk about what the different groups did
- students need to know how to use many strategies and then be able to choose which one they need for what they want to do
- you need to know what the problem is
- you should have a good idea what the outcome might be; estimate
- write number sentences
- they need to be systematically taught those things
- use manipulatives to help them develop a picture in there mind
- skills like basic facts need to be learned but I tell them to practice at home, we don't have time for that here
- I try to relate things to something that they already know
- the children should enjoy it

Eighth Grade Teacher

- introduction of the new material, guided practice, enrichment activity, then one or two days working on the nuts and bolts, what are we going to do with this stuff once we know it
- focus a bit more on the concrete, pictorial type things
- stay away from worksheet stuff where you have a problem with a set of numbers [with no picture]
- I used to teach rules and give practice, but I know now that it is better to let the kids explore and figure things out for themselves
- it may take more time now but if the kids really understand it will be there later when they need it as the basis for another concept
- I think some of them thoroughly enjoy it. students should feel it is safe to make mistakes safe to sit around and discuss it with other kids
- general willingness to explore things that might work
- give them the tools, calculators and computers, so they can check and recheck their work
- they do not look at problem solving as negative and are willing to do most any problem they are given

What is Problem Solving

Third Grade Teacher

- being presented with something that you do not know the answer to right away
- investigations for which there can be many answers and many strategies
- gives the reason for manipulating numbers

Eighth Grade Teacher

- problem solving is not the four of five problems at the end of the page that are written out instead of numerically (represented) but problem solving is thread that runs though everything
- many teachers use the five golden steps of problem solving for five days while they work on word problems and then do nothing else for the rest of the year. doesn't let you think creatively
- problems out of the book maybe once a month, other problems kids write them and newspapers and soft cover problem solving books, for example stock market, sport statistics.

Use of Textbooks

Third Grade Teacher

- they are available but as a rule we hardly ever use them
- they books give an explanation and then drill and practice, the students forget whatever they do in the book, I believe that children need to do worthwhile tasks

Eighth Grade Teacher

- use the textbook often
- textbooks lack a variety of problems, they pigeon hole types of problems together mostly one and two step, non-vague
- they need some problems that are not so clear cut where kids have to stretch a little to find out what is going on

Group work

Third Grade Teacher

- more group than individual
- lower students have the support of the group and can hear what other students have to say, this helps them to become stronger in math and to focus on what they should be doing
- that makes it harder to grade

Eighth Grade Teacher

- yes I do that often
- work in small groups and debrief as a whole class
- or two small groups on the same problem get together and compare notes

Assessment

Third Grade Teacher	Eighth Grade Teacher
• I tend to grade them more by their participation in the process • understanding the process is more important than the correct answer • has given group tests, some complain that so and so did not do it all, but each person has a job in the group to do,	• try to write multi section problems where you do this then use that answer to do that and so on

Calculators

Third Grade Teacher	Eighth Grade Teacher
• I think they are perfect for problem solving because you don't have to worry about the computations	• another tool like a pen

Advice to Other Teachers

Third Grade Teacher	Eighth Grade Teacher
• know what kids need to know and then find situations the children can use a vehicles to learn those skills	• don't spent most of your time having kids memorize formulas

Observations

Each of the teachers was also observed three times teaching mathematics. They were asked to present a lesson in problem solving that was typical of what they would usually do in their classrooms. The teachers were aware of the observation times at least one week in advance.

Third Grade

First observation The class was working on what might be called an open ended problem solving activity using pattern blocks. The students' desk were arranged in groups of three or four and remained that way at all times. The pattern blocks represented different shaped tables. Students working in groups were to design a table arrangement for

seating 100 students. Each group was given a specific pattern block shape to use. After a sufficient period of time for most groups to finish their work, the teacher called upon the group that had used triangular tables. The teacher recorded information generated by the group on the chalkboard for all to see. The students were asked to write a number sentence to express the pattern they saw. Other groups with other shapes were called upon in a similar manner. Other number sentences were written. The class proceeded until each group had a chance to respond.

Second observation On my second visit to the third grade classroom the students were again working on an open-ended problem solving activity. The students were presented with the results of a hypothetical school Olympics competition. The data included the names of five participants and each of their scores (e.g., elapsed time, distance) for each event (e.g., 100 yard dash, shot put). The students were asked who should be named the overall winner of the Olympics? Students working in groups had to devise a system, find the first place winner, and explain their system for determining the winner to the rest of the class.

Third observation On my final observation of the third grade class the students were in groups working on another open-ended problem solving situation, a simulation called Travel Arizona. This multi-day project required groups of students to plan driving trips around Arizona. Each day they logged miles driven, plotted current location on a map, recorded expenses for gasoline, planned meals, recorded food expenses, and so forth. After approximately 35 minutes the teacher had the groups talk about where they had gone that day and decisions that were made. She also asked the groups to list the types of mathematics that they used to complete their tasks.

Eighth Grade

First observation On my first observation in the eighth grade the class was working on area and perimeter problems. The students moved their desks into groups to work on a page of problems handed out by the teacher and calculators were distributed. The problems were from various professions, for example, painter, machinist. After about 20 minutes, students were called on to give the answer to each problem. If the answer was correct, then the student was asked to explain how they had arrived at the answer. When all groups had responded the teacher used several objects (a pyramid, a can lid, a flattened tissue box, a tissue box) to ask the class about area and volume. In a few minutes it was decided that area has two dimensions and volume has three dimensions. The students returned their desks to rows before they left the classroom.

Second observation On my second observation the students were working on computing the volume of specific shapes. The students, working in group of two, were asked to solve a problem from a page in the textbook about the volume of a buoy. As they began to work, the teacher wrote four formulas for volume on the chalkboard (rectangular solid, pyramid, cylinder, cone). About 10 minutes later the students are asked to explain what they did. Many students seemed to be having difficulty with the problem, so the teacher worked through the problem step by step while using models of the shapes involved to demonstrate the terminology (e.g., diameter, height).

Third observation On my final observation the students were involved in some guided discovery. The teacher asked them to pick a number between 1 and 100, enter it on the calculator, press the square root key, and record both the original number and the resulting number. After several minutes the teacher challenged the students to explain what the square root key did to a number. After several students responded, they were introduced to the idea of cube roots and asked about adding square roots and multiplying square roots.

The teacher worked a few examples on the board and assigned problems about square roots out of the book as homework.

Discussion

The results of the survey portion of this study present somewhat optimistic results regarding teachers' instructional techniques and beliefs about mathematics problem solving instruction. In most cases teachers agreed to what is recommended and disagreed with what is not. Although this study did not validate the results of the survey in any systematic way, it can at least be concluded that teachers are aware of the recommendations for instruction even though they may not be implemented.

There are three responses, however, that indicate possible misalignment with the *Standards*. The first of these concerns manipulative use. Teachers were asked about the frequency with which they have their students to model problem with manipulatives. The mean of responses ranged from 4.09 (K-3) to 2.27 (7-8) (See Table 3). This indicates that the use of manipulatives drops off rather dramatically as grade level increases. This was validated to some degree by the interviews and observations. The third grade teacher said that manipulatives helped her students to form pictures in their minds. In the third grade class students used manipulatives to solve the problem about arranging tables for a banquet. In contrast, the eighth grade teacher refers to talking about and focusing on concrete, pictorial types of things. This was seen in his classroom when he used models to help the students visualize the various shapes of which they were finding volume and also the diagrams presented with the area and perimeter problems. However, in the eighth grade the students were not allowed the opportunity to use the manipulatives as they solved problems.

Second, teachers responded positively to students needing to know the key word approach to problem solving. Mean responses ranged from 3.34 (K-3) to 3.88 (7-8) (See Table 6). The key word approach suggests that recognizing a keyword in a problem will

enable the student to pick an operation and solve the problem. This approach does not emphasis the importance of understanding the problem situation. Teachers' mild agreement, increasing at the higher grade levels, with this statement is contrary to the recommendations. This phenomenon may be linked to textbook use as a sources of problems. At the K-3 level teachers rated textbooks as 2.79, whereas at the 7-8 level teachers ranked them more useful, 3.45 (See Table 4). Textbooks tend to contain the routine types of problems that can be solved using the keyword approach. More frequent use of textbooks might increase the tendency for teachers to use the keyword approach. The changing perception of textbooks by grade level was also apparent in both the interviews and observations. The third grade teacher reported that she seldom used textbooks in her class. Textbooks were not used during any of the observations. The eighth grade teacher, although he stated that he did not like the type of problems presented in textbooks, reported that he used the them often. Textbooks were used as a source of problems for classwork and homework during the observations.

Third, there was a discrepancy between the perceived usefulness of calculators and the actual use of calculators (See Table 7). Teachers at all grade levels agreed to some extent that calculators were useful for solving word problems. However, they tended to disagree or be undecided when asked if they allowed students to use them. This discrepancy was apparent in the interviews and observations at the third grade level. Although the teacher thought that calculators were perfect for problem solving, her class did not use calculators during the observed lessons. In the eighth grade, the teacher stated that calculators were like another tool like a pen, and calculators were always distributed to his students during the observations.

In addition to these possible misalignments with recommendations for instruction, I think that two other area merit discussion. First, the issue of student interest in problem solving. Based on results from the survey (See Table 5), student interest in problem solving tends to decrease at the higher grade levels. Interestingly, both teachers interviewed for

this project reported that their students were interested in problem solving. During the observations, students at both grade levels appeared to be on task and willing to share their ideas. At the eighth grade level, the teacher commented on making the students feel that is was safe to make mistakes and sit around and discuss problems with each other. Possibly the comfort of a safe environment for problem solving helped those students to maintain interest in problem solving.

Lastly, a few comments on the type of problem solving observed in the classrooms and commented on in the interviews. Although both teachers were convinced that problem solving was important and both conducted problem solving instruction in much the same way, that is , introduction, group work, discussion; their ideas about problem solving and their choices of problems to solve seemed quite different.

The third grade teacher viewed problem solving as finding an answer that was not immediately apparent, investigations with multiple answers, and ultimately the reason for manipulating numbers. This view was apparent in the open-ended questions she used as the basis of her instruction. Even when the project involved applications of mathematics in a real world situation (Traveling Arizona), the problems were stated as open-ended with multiple solutions. The students were actively involved in problem solving.

The eighth grade teacher saw problem solving as a thread running through mathematics and used on a day-to-day basis. He objected to the view of problem solving as the few word problems interspersed in textbooks. The eighth grade teacher sought to make mathematics real for his students by showing them the applications of what they were learning. He used problems derived from information in newspapers or found in problem solving books. However, the applications were typically problems with one correct answer. The third grade teacher seemed to use problem solving as a vehicle to engage her students in mathematics. By the eighth grade, the teacher was more interested in solving problems through the use of mathematics.

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Table 1

Number and Percentage of Teachers by Grade Level, Gender, Degree Earned, and Classroom Type

		Gender		Highest Degree		Type of Classroom		
Grade	N	*F*	*M*	*BA/BS*	*MA/MS*	*Closed*	*Deprtmt*	*SpEd.*
K-3	371	356	14	239	131	335	4	10
	(50%)	(96%)	(4%)	(64%)	(35%)	(90%)	(1%)	(3%)
4-6	281	225	50	152	126	206	55	9
	(38%)	(80%)	(18%)	(54%)	(45%)	(73%)	(20%)	(3%)
7-8	94	50	43	58	35	7	78	2
	(13%)	(53%)	(46%)	(61%)	(37%)	(7%)	(83%)	(2%)
Total	746	631	113	449	292	548	137	21
		(85%)	(15%)	(60%)	(39%)	(73%)	(18%)	(3%)

Note. Not all data sum to 100% due to missing responses on some of the surveys.

Table 2

Teachers' Mean Years of Experience and Time Dedicated to Mathematics Instruction and Inservice by Grade Level

Grade	Total Years in Teaching	Years at Grade Level	Hours /Week on Math	Hours /Week on Prob Solve	Inservice Days /Year
K-3	12.1	6.1	4.7	1.9	1.2
4-6	12.1	5.2	5.0	2.0	1.1
7-8	11.8	6.6	11.6	3.5	1.5

Table 3

Mean Responses to Items by Grade Level

	K-3	4-6	7-8
Students work in small groups or with a friend.	3.75	3.44	3.48
Students model problems with manipulatives.	4.09	2.83	2.27
Students explain how they had solved a problem.	3.77	3.66	3.73
Teacher asks for different ways to solve the same problem.	3.52	3.44	3.76
Students are asked to defend their reasoning and answer.	3.28	3.46	3.94

Note. 5-most of the time, 4-often, 3-sometimes, 2-not very often, and 1-not at all.

Table 4

The Perceived Usefulness of Sources for Word Problems by Grade Level

Source	K-3	4-6	7-8
Textbooks	2.79	3.46	3.45
Teacher	3.96	3.81	3.79
Supplemental	4.02	4.16	3.80

Note. 5-very useful, 4-useful, 3-average, 2-not very useful, and 1-not at all useful.

Table 5

Teachers' Assessments of Self and Students

	K-3	4-6	7-8
Your own problem solving ability.	3.10	3.20	3.33
Your skill in teaching problem solving.	3.00	3.01	2.88
Your motivation to teach problem solving.	3.17	3.23	2.97
Your students' problem solving ability.	2.47	2.26	2.12
Your students' interest in problem solving.	2.62	2.15	1.97
Your students' effort in problem solving.	2.55	2.40	2.21
Your students' ability to discuss their problem solving work.	2.29	2.42	2.21

Note. The highest possible rating on this table is 4.
4-A, 3-B, etc.

Table 6

Mean Responses to Negatively Phrased Statements

	K-3	4-6	7-8
It is better to tell students how to solve problems than to let them discover how on their own.	2.12	2.29	2.69
Teachers should tell students the best way to solve each type of problem.	2.15	2.14	2.73
Getting the correct answer should be the main focus of problem solving in elementary school.	2.15	2.17	2.30
Students need to be given the right answer to all of the problems they work.	2.63	2.81	3.18
Hearing different ways to solve the same problem confuses children.	1.99	2.00	1.94
Students need to know the "key word" approach to problem solving.	3.34	3.66	3.88
It is more important for children to compute efficiently, than to solve word problems.	2.10	2.16	2.30

Note. Low means on this table indicate alignment with recommendations.
5=strongly agree, 4= agree, 3= undecided, 2= disagree, and 1= strongly disagree)

Table 7

Mean Responses to Positively Phrased Statements

	K-3	4-6	7-8
The best way to become a good problem solver is to solve a lot of problems.	3.74	3.57	3.73
Problem solving should be the major emphasis of mathematics instruction.	3.72	3.56	3.48
Children can develop their word problem solving skills by working together in small groups.	4.05	4.12	3.79
Calculators are useful in solving word problems.	3.55	3.53	3.85
I allow my students to use calculators when they are solving word problems.	2.24	2.40	3.06
My students solve word problems every day.	3.34	3.20	3.55

Note. High means on this table indicate alignment with the recommendations. 5=strongly agree, 4= agree, 3= undecided, 2= disagree, and 1= strongly disagree)